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The Four-line Algorithm for the Treatment of Unilateral Cleft Lip

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Background: Several factors affect the outcome of a repaired unilateral cleft lip (UCL). Some of these, like the surgeon's expertise, are hard to evaluate, whereas others can be better evaluated objectively using the cleft severity index and the surgical technique used.

Methods: This study includes patients of Operation Smile Ecuador and was done in 2 parts. The retrospective part uses the medical records of 298 patients with UCL treated by Operation Smile Ecuador from January 2015 to December 2017. The correlation of the photographed measurements, surgical technique, and evolution of the patients was studied. In the prospective part, the participant surgeons of this article applied the algorithm to 136 patients treated from January 2018 to December 2019.

Results: In the retrospective study, the resulting symmetry varied significantly among most Unilateral Cleft Asymmetry Index presurgical classifications, and 34% of the results were deficient. The four-line algorithm was developed using the case-technique analysis of the retroactive study. The algorithm was applied in the prospective part, which resulted in no deficient cases and 81% optimal results. There were significantly better results after applying the four-line algorithm for patients classified as Unilateral Cleft Asymmetry Index degrees III and IV ($P < 0.001$ and $P = 0.041$, respectively).

Conclusions: Even though the cleft severity in the UCL is an important prognostic factor, the results of this study show that there are no universal surgical techniques to achieve optimal results. The four-line algorithm proposes to use a case-specific surgical technique to achieve the best functional and aesthetic result for our patients.
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INTRODUCTION

Facial anomalies can physically and psychologically mark a patient and their family for life. It is an obligation of the medical team to give these patients the best possible treatment so that they can functionally develop. Unilateral cleft lip (UCL) is by far the most common facial anomaly, representing 95% of cases.[1] The cheiloplasty seeks the creation of a full upper lip of adequate height and symmetry.[2]

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Several methods have been described, but "panacea" has not been found for the repair of UCL. Although straight-line techniques provide a very good cosmetic scar, they do not compensate for the vertical lack of tissue on the cleft side; thus, symmetry is seldom achieved.[3] On the other hand, techniques that are usually successful in reaching an adequate height, such as Millard and Mohler, leave a more visible scar.[4] There are also techniques, such as Tennison and Skoog, that leave a very visible scar and sometimes leave even a longer lip on the cleft side; however, in some severe cases, these techniques are the only way to compensate for very short medial and/or lateral segments of the cleft lip.[5,6]

Thus, there are several factors that influence the final result of the UCL treatment. For some of these, such as the surgeon's skill and experience or the pre- and postoperative care, it would be very hard to find an objective evaluation method.[7,8]

An important factor is the severity of the cleft. As cited by Fisher et al,[9] "the final appearance of the lip and nose is determined by several factors; however, the

Disclosure statements are at the end of this article, following the correspondence information.

greatest determinant is the severity of primary deformity." Although this would be an easier-to-assess factor, an objective and applicable universal method has not been achieved.[10] In September 2017, Campbell et al[11] proposed the "Index of Severity of the Fissure of the Unilateral Cleft Lip" as a tool for assessing UCL repair outcomes. This index classifies UCL into 4 categories according to the severity of the primary cleft.

However, we often see very inconsistent results, even though it is the same surgeon, the same surgical technique, and the same Campbell severity index. There are a range of factors that contribute to the inconsistent results, such as variations of nasal anatomy, that require subtle technique adjustments and the difficulty in predicting long-term outcomes of a cleft repair.[12] Also, at times the most experienced surgeons choose one surgical technique or another on a case-by-case basis, without describing a clear reason why.

In this article, we present a two-part study. First is a retrospective study, which analyzes cases of patients with UCL treated during 2015, 2016, and 2017. The analysis of the results allows us to formulate an algorithm for the evaluation and choice of treatment of UCL, taking into account its characteristics and the specific benefits of each surgical technique. In the second part, the algorithm is prospectively applied for 2 years, 2018 and 2019, and the reliability and applicability of the algorithm were analyzed.

RETROSPECTIVE STUDY

A retrospective study was carried out analyzing the medical records and photographic archives of patients with UCL that presented to Operation Smile Ecuador (OSE) during from January 2015 to December 2017.

Methods

The medical records of 298 cases were analyzed, and the following data were collected:

Takeaways

Question: How can a surgeon decide what technique to choose when repairing a cleft lip to reduce scarring and maximize function?

Findings: The four-line algorithm provides surgeons with a tool to choose a technique that will produce an ideal result based on a combination of cleft severity and a technique's tissue compensation.

Meaning: Surgeons can use this tool to choose the technique that will yield an ideal result based on the severity of the cleft, which could also improve patient happiness.

1. Presurgical data: universal cardinal marking points and lip dimensions of presurgical photographs (Fig. 1A).
2. Postsurgical data: Lip dimensions at first week, first month, and sixth month.
3. Surgical technique.
4. Complications.

Definition of the 4 Lines

Using the universal cardinal marking points, from the presurgical study in UCL, we draw 4 lines, as seen in Figure 1B:

A. Between the apex of the cupid arc and the base of the healthy side columnella (2–6).
B. Between the apex of the cupid arc and the base of the cleft side columnella (3–8).
C. Between the Noordhoff point and the base of the nasal wing on the cleft side (4–9).
D. Between the apex of the cupid's arc and the base of the nasal wing of the healthy side (2–7).

Presurgical Data

Because the retrospective study was carried out using data from photographic archives, we agreed that the difference between the 4 lines should be considered in terms

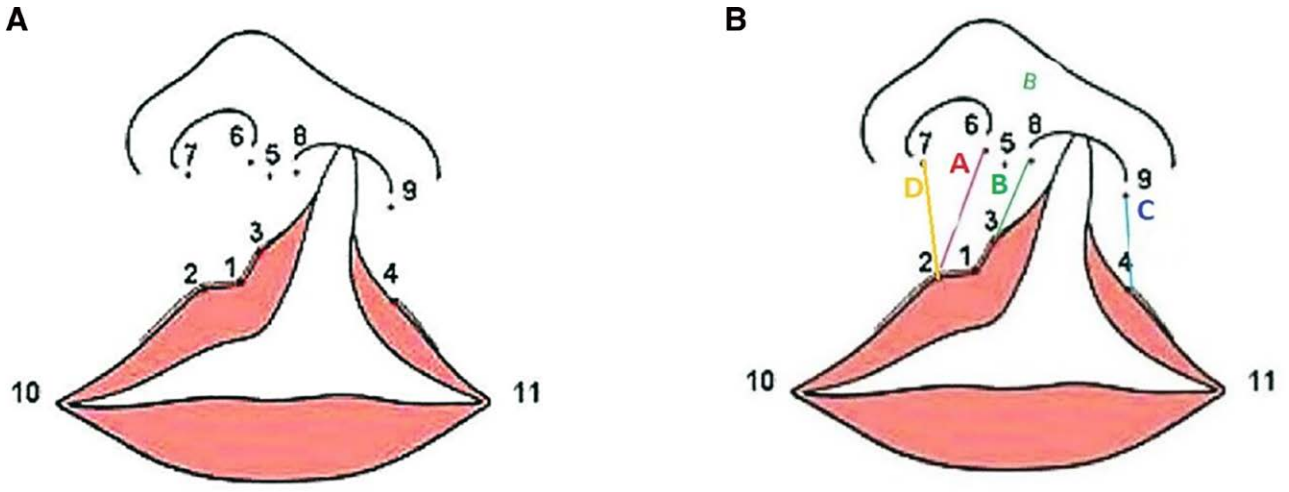

Fig. 1. Anatomical markings for unilateral cleft lip and associated surgical lines. A, Universal cardinal marking points. B, Presurgical lines based on universal cardinal marking points.

of percentage instead of millimeters. This would also be consistent with the fact that in real life, we would be treating patients of different ages, races, sexes, and sizes. From the collected data of the 298 charts, we looked at the difference between lines A–B (medial) and C–D (lateral) of the presurgical 4-line measurements. We proposed the Unilateral Cleft Asymmetry Index (UCAI) to classify the presurgical results of our study (Fig. 2).

Postsurgical Data

The analysis of postsurgical results evaluated the symmetry of the lip in what concerns its height. We classified the results according to Figure 2 and graded the symmetry as optimal if it is symmetrical, acceptable if the difference is less than 10%, and deficient if the difference is more than 10% (Fig. 3).

Unilateral cleft asymmetry index (UCAI)

GI: Line B or C = or 5% dif. than line A or D.
GII: Line B or C 5 – 25% dif. than line A or D.
GIII: Line B or C 25 – 50% dif than line A or D.
GIV: Line B or C +50% dif. than A or D

Fig. 2. Unilateral Cleft Asymmetry Index.

Symmetry

Optimal: Symmetric
Acceptable: Less than 10% of diference
Deficient: More than 10% of diference.

Fig. 3. Classification of lip symmetry postsurgery.

Surgical Techniques

Surgical techniques were grouped according to the amount of tissue they contribute to lengthening the short segment of the deformity and the noticeability of the resulting scar (Fig. 4):

None: Such as vertical or straight-line technique, with no contribution of tissue.

Minimal: Such as the Fisher technique, with minimal contribution of tissue.[12]

Moderate: Such as Millard or Mohler, with moderate contribution of tissue.[13]

Major: Such as Tennison or mixed, with a large contribution of tissue.[14]

Complications

Cases in which there were complications, such as infection, dehiscence, and so on, were grouped here and excluded from the study.

Outcomes Analysis

Results were analyzed by comparing the surgical technique, presurgical UCAI classification, and the postsurgical outcome using Microsoft Excel (Microsoft Corp, Redmond, WA, USA). Data analysis included descriptive results and chi-square tests with significance marked at a *P* value less than 0.05.

Results

Presurgical Data

In the analysis of lines A and B, we found that line B was shorter than line A in every case. Of the 298 cases,

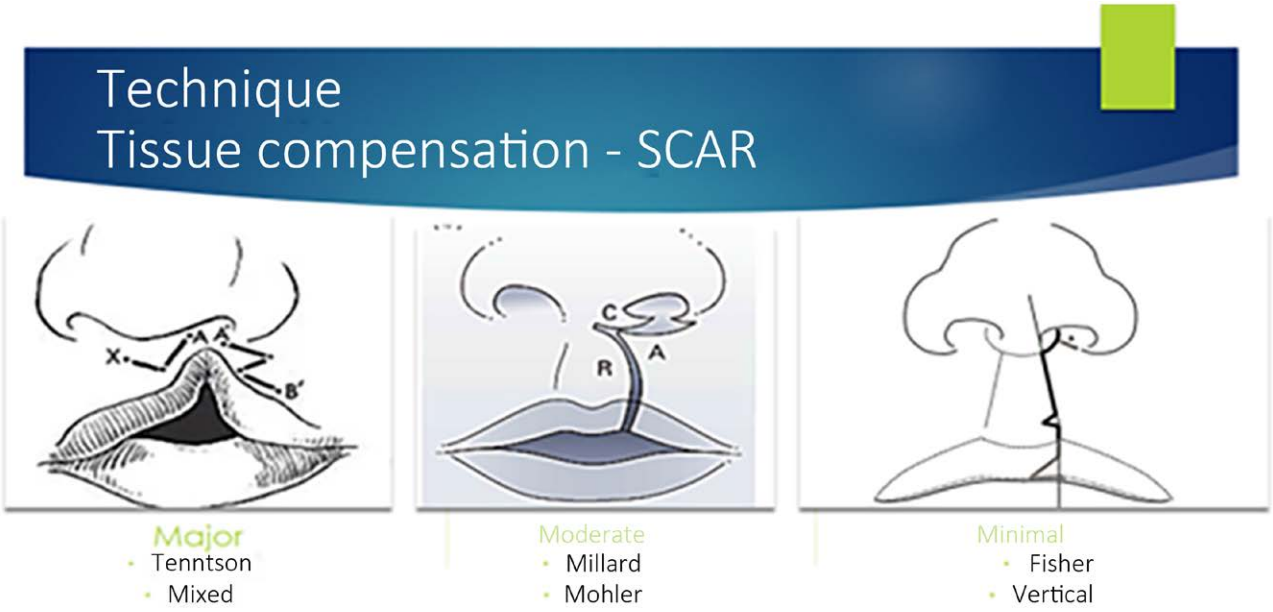

Fig. 4. Tissue compensation groupings based on resulting scar.

using the UCAI, we found that most cases were grade II (GII) (43%) and the fewest were grade IV (GIV) (4%) (Table 1). When comparing the difference between lines C and D (the lateral measurements), in most of the cases the cleft side was shorter, except for 3 cases where the cleft side was larger than the normal side. According to the UCAI with the lateral measurements, most cases were grade I (GI) degree (52%) and none of them were GIV (0%) (Table 1).

Postsurgical Data

Postsurgical results were analyzed by the lead author and discussed among the article authors. Bias was addressed objectively by the use of the grading chart in Figure 4. In the analysis of postsurgical symmetry, we observed acceptable or deficient symmetry in most of the cases, whereas the goal is optimal symmetry (Fig. 5).

Surgical Technique

Overall, moderate tissue contribution techniques were most used (50%), followed by minimal (41%), and major and no tissue contribution were least used (4%, each) (Fig. 5).

Complications

There were complications in 15 cases (5%). These cases were excluded from further study.

Outcomes Analysis

Overall comparison of the surgical technique and postsurgical symmetry shows that optimal symmetry was achieved the most (50%) in vertical-type techniques with no tissue contribution, followed by Tennison-type with major tissue contribution (46%); Millard- or Mohler-type with moderate tissue contribution (45%); and finally, Fisher-type with minimal tissue contribution (42%); Deficient results occurred the most in the Fisher-type techniques (39%) and the least in the Tennison-type techniques (15%). Overall, moderate tissue contribution techniques were the most commonly used (50%), followed by minimal (41%), with major and no tissue contribution accounting for 4% each (Fig. 5).

Presurgical UCAI of the medial portion was used to contrast the surgical technique and presurgical UCAI. There was significant variation in postsurgical outcomes among GII ($P = 0.009$), GIII ($P < 0.001$), and GIV ($P < 0.001$). Patients with UCAI GII had the most optimal results with moderate tissue contribution techniques (74%), whereas no tissue contribution techniques had the most deficient outcomes (57%). Among UCAI GIII, most patients either received minimal (n = 40) or moderate (n = 33) tissue contribution techniques. The GIII minimal tissue contribution outcomes were mostly deficient (85%), whereas the moderate tissue contribution techniques were mostly optimal (55%). UCAI GIV patients only received moderate tissue (n = 51) or major tissue contribution (n = 6) with deficient outcomes for 80% of the moderate tissue contribution and optimal outcomes for 67% of the major tissue contribution (Fig. 5).

Deficient symmetry (10% or more) was found on the lateral side of the cleft (line D), in 34 cases (11%), all of them in GIII UCAI. We did not find remarks in the surgical protocols about any technique used to solve this asymmetry.

Discussion

Overall, the retrospective study supports the hypothesis that the surgical technique used influences lip symmetry but is dependent on the UCAI as the more severe degrees resulted in more deficient outcomes. Straight-line techniques result in a cosmetically appealing scar, but they poorly compensate for the vertical lack of tissue on the cleft side; therefore, symmetry is only achieved in select cases. Fisher et al.[9] addressed the issue of compensation to create more symmetry through presurgical columellar angle and nostril width measurements. Techniques with minimal tissue contribution, such as the Fisher technique, leave a minimal scar, but an optimal or tolerable symmetry is only achieved in cases with a GII UCAI. In GIII cases, good symmetry was achieved only in 20%.

On the other hand, techniques that are usually successful in reaching an adequate height, such as Millard and Mohler, leave a more visible scar. Techniques such as Tennison and Skoog leave a very visible scar and sometimes even a long lip on the cleft side, but, in some severe cases, it is the only way to compensate for a very short cleft lip. In terms of symmetry, 1 study that evaluated surgical outcomes for 20 years found that upper rotation advancement plus double unilimb Z-plasty led to better lip symmetry for patients with moderate tissue deficiency, whereas a triple unilimb Z-plasty led to better lip symmetry for patients with severe tissue deficiency.[15] A mixed technique is also an excellent alternative for severe cases with the benefit of a better cosmetic scar.

Symmetry of the lateral side of the cleft may also need compensation. In the retrospective part of this study, there

Table 1. Symmetry Severity by UCAI Classification of the Medial and Lateral Portions in the Retroactive (Before) and Prospective (After) Studies

		UCAI Classification			
		GI	GII	GIII	GIV
Retroactive	Medial (A–B)	61 (20%)	127 (43%)	98 (33%)	12 (4%)
	Lateral (C–D)	154 (52%)	93 (31%)	51 (17%)	0 (0%)
Prospective	Medial (A–B)	24 (18%)	59 (43%)	51 (38%)	2 (1%)
	Lateral (C–D)	71 (53%)	42 (31%)	22 (16%)	0 (0%)

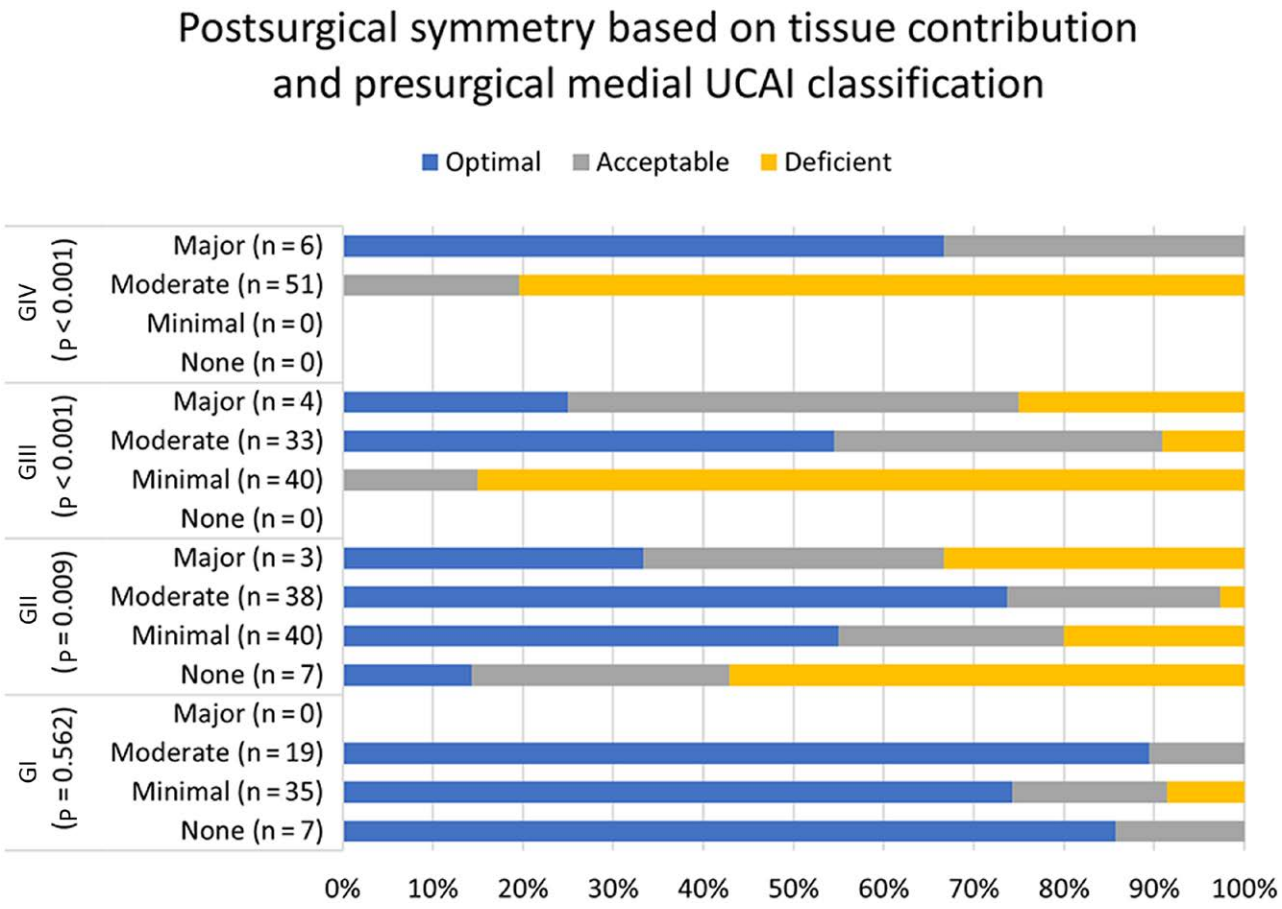

Fig. 5. Postsurgical analysis of symmetry based on tissue contribution and presurgical medial UCAI classifications in the retroactive study.

is no described technique used for this purpose, leaving 11% of the cases with an evident asymmetry.

The retrospective study supports the hypothesis and previous literature showing that surgical technique greatly influences the aesthetic results of lip repair. With this evidence, we formulated the "four-line algorithm" that applies the medial and lateral UCAI to select the most optimal surgical technique and achieve 2 objectives: a symmetrical result and the least possible perceptible scar.

Table 2. The Four-line Algorithm Demonstrating the Suggested Techniques Based on Medial and Lateral Portioning

The Four-line Algorithm		
	Surgical Technique	
UCAI	Medial Portion	Lateral Portion
GI	Vertical	
GII	Fisher	Fisher
GIII	Millard	Mixed
GIV	Mixed	

PROSPECTIVE STUDY USING THE FOUR-LINE ALGORITHM

Methods

In this part of the study, the four-line algorithm is applied to 136 patients with UCL who presented to OSE from January 2018 to December 2019. All procedures were performed by the authors of this article. The following data were collected:

1. The 4-line (A–D) presurgical measurements. The four-line algorithm is summarized in Table 2.
2. The UCAI degree and the surgical technique used.
3. The measurements of the lines in the postsurgical controls at first week, first month, and sixth month.
4. Complications.

Methods in the prospective portion of the study were consistent with the methods of the retroactive study.

Surgical Technique

The authors applied the four-line algorithm to determine which techniques resulted in the best outcomes for the respective UCAI classifications.

Results

Presurgical Data

Using the UCAI for the medial portion, most patients were GII degree (43%) and the least were GIV (1%).

Using UCAI for the lateral portion, most patients were GI (53%), whereas the least were GIII (16%), and none were GIV (Table 1). The patient classifications for the prospective study are in similar proportions to the classifications of the retroactive study, which makes these sets of data comparable.

Postsurgical Data

After applying the four-line algorithm for all 136 cases, there were mostly optimal results (84%), and no case had deficient asymmetry of more than 10% between the normal and the cleft sides. Patients with GI classification had similar results before and after the four-line algorithm, with 80% of patients achieving optimal results; however, there were no deficient results after the four-line algorithm compared with 5% before. These results were not statistically significant ($P = 0.456$). The most significant change in outcomes was in the GIII patients, where 51% had optimal or acceptable outcomes before the algorithm, and 100% had optimal or acceptable outcomes after the algorithm was applied ($P < 0.001$). Likewise, 100% of GIV patients had optimal or acceptable outcomes after the algorithm compared with only 28% before, which was statistically significant ($P = 0.041$) (Fig. 6).

Surgical Technique

Due to scar quality, surgeons selected techniques with minimal scarring that follow anatomical folds, for example, vertical and Fisher, less often than techniques that leave larger scars and cut the anatomical folds, for example, Millard and Mohler.

Patients with medial UCAI GI had optimal outcomes when surgeons used the vertical or straight-line techniques, leaving a cosmetically appealing scar and a symmetrical lip due to almost complete compensation using the Rose–Thompson effect. The Fisher technique can successfully be applied in cleft lips with UCAI GI or GII, leaving a very cosmetically appealing scar and excellent symmetry in the lip. In a UCAI GIII, a good result is less probable. The Millard- or Mohler-type techniques would leave a too visible scar if they were used in cleft lips with a UCAI GI or GII degree, but they are the best choice for a UCAI GIII. The Tennison- or Skoog-type techniques are good for UCAI GIV cases, but they leave a very evident scar; therefore, we recommend the mixed technique (Fisher + Millard) that leaves a less evident scar while achieving good symmetry.

For patients with lateral UCAI GII, the surgeons considered the use of Fisher variant 2 (for short). In UCAI GIII, we considered adding the Percy Rossell triangle to improve outcomes.[16]

Discussion

Many factors influence the outcome of UCL treatment, the 2 most important being the severity of the cleft and the surgical technique that was used. As this study suggests, these should be considered interdependently, and not separately. The large number of surgical techniques described for the treatment of UCL and the persistent

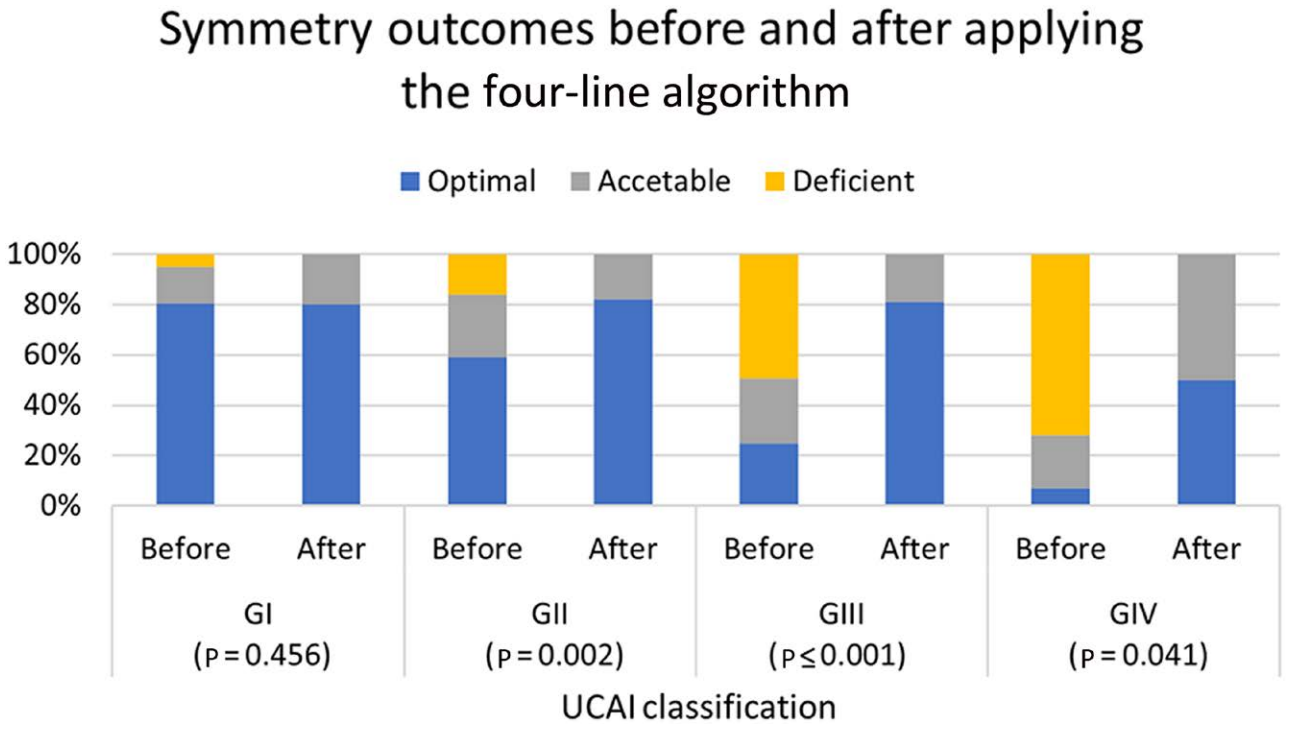

Fig. 6. Symmetry severity by UCAI classification of the medial and lateral portions in the retroactive (before) and prospective (after) studies.

inconsistency in the results reflect that a master technique has not yet been found.[17] In most cases, this is not due to errors in the technique, but because none of the techniques are universally applicable, as shown in the retrospective study.

The results of the prospective study compared with the retroactive study show the effectiveness of the four-line algorithm in producing more optimal outcomes. In the retroactive study, the highest reported optimal outcome was 42% of patients (vertical-type/no tissue contribution technique) compared with 82% of patients in the prospective portion (Fisher). Notably, there were no patients with a deficient outcome across all UCAI classifications in the prospective study compared with 11% of patients in the retroactive study. This demonstrates the utility of the four-line algorithm in selecting a technique for the best symmetry outcomes.

This study is limited by the cases presented to OSE in the study period, of which only 2 were the most severe UCAI classification, GIV. Deficient symmetry was most notable in GIV cases of the retroactive study, so the limited sample size in the prospective study limits the conclusiveness of these results.

CONCLUSIONS

Although previous literature addresses the symmetrical results of one technique over another, the results of the prospective study show that the four-line algorithm can provide a practical and efficient guide to choosing the best surgical technique using the UCAI degree, with the goal of achieving optimal symmetry with the least evident scar.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

1. Dixon MJ, Marazita MI, Beaty TH, et al. Cleft lip and palate: synthesizing genetic and environmental influences. *Nat Rev Genet.* 2011;12:167–178.
2. De Ladeira PR, Alonso N. Protocols in cleft lip and palate treatment: systematic review. *Plast Surg Int.* 2012;2012:562892.
3. Grewal JS, Yanik SC, Strohl-Bryan AM, et al. The unilateral cleft lip repair. *Am J Otolaryngol.* 2021;42:102908.
4. Kwong JW, Cai LZ, Azad AD, et al. Assessing the Fisher, Mohler, and Millard techniques of cleft lip repair surgery with eye-tracking technology. *Ann Plast Surg.* 2019;82:S313–S319.
5. Falk-Delgado A, Lång A, Hakelius M, et al. The Skoog lip repair for unilateral cleft lip deformity: the Uppsala experience. *Plast Reconstr Surg.* 2018;141:1226–1233.
6. Gatti G, Freda N, Giacomina A, et al. Cleft lip and palate repair. *J Craniofac Surg.* 2017;28:1918–1924.
7. Bonanthaya K, Jalil J. Management of the nasal deformity in the unilateral cleft of the lip and nose. *J Maxillofac Oral Surg.* 2020;19:332–341.
8. Shaw WC, Dahl E, Asher C, et al. A six center international study of treatment outcome in patients with cleft of the lip and palate. *Cleft Palate Craniofac J.* 1992;32:434–441.
9. Fisher DM, Tse R, Marcus JR. Objective measurements for grading the primary unilateral cleft lip nasal deformity. *Plast Reconstr Surg.* 2008;122:874–880.
10. Mosmuller DG, Griot JP, Bjinen CL, et al. Scoring systems of cleft-related facial deformities: a review of literature. *Cleft Palate Craniofac J.* 2013;50:286–296.
11. Campbell A, Restrepo C, Deshpande G, et al. Validation of the unilateral cleft lip severity index for surgeons and laypersons. *Plast Reconstr Surg Glob Open* 2017;5:e1479.
12. Fisher DM. Unilateral cleft lip repair: an anatomic subunit approximation technique. *Plast Reconstr Surg.* 2005;116:61–71.
13. Millard DR. *Cleft Craft. The Evolution of Its Surgery, I: The Unilateral Deformity.* Little Brown & Co Editores; 1976:251.
14. Tennison CW. The repair of unilateral cleft lip by the stencil method. *Plast Reconstr Surg.* 1952;9:115–120.
15. Rossell P. A 20-year experience in unilateral cleft lip repair: from Millard to the triple unilimb Z-plasty technique. *Indian J Plast Surg.* 2016;49:340–349.
16. Rossell-Perry P. The marginal branch triangle: anatomic reference for its location and preservation during cosmetic surgery. *J Plast Reconstr Aesthet Surg.* 2016;69:387–394.
17. Bansal A, Reddy SG, Chug A, et al. Nasal symmetry after different techniques of primary lip repair for unilateral complete cleft lip with or without cleft of the alveolus and palate: a systematic review. *J Craniomaxillofac Surg.* 2022;50:894–909.